SHORELINE EXTRACTION FROM OPTICAL IMAGES: A CASE STUDY IN IGOUMENITSA/GREECE

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Abstract

Climatic, geodynamic and anthropogenic driving forces move the shoreline. The amount of this movement is of paramount importance for protection, development and management of the coastal area. In order to do this, the historical positions of the shoreline are needed to be extracted from air photographs and satellite imagery. But, air photographs taken several decades ago are of a small scale and the extraction of the shoreline cannot be carried out accurately. It is understood that mixing shorelines extracted from different imagery scales, influences the accuracy of the estimation of the shoreline change rate.
The common procedure to study shoreline change rate starts with the digitization of the shoreline from the available geoinformation. The problem with this procedure is that it is executed manually and involves the personal characteristics, assessment and experience of the operator. The purpose of the present work is to discuss a methodology of an automatic extraction of a shoreline mapped on two air photographs with different scales and compare the results. To serve this, a Matlab program is formulated and different extraction techniques are applied to extract the shoreline without operator's intervention. The Canny, Zero-cross and Prewitt methods are used and their results are compared. It is concluded that, block division of the optical images does not help the shoreline detection and the scale of the image is important as far the selection of the appropriate method is concerned.

Keywords: beach evolution, climate change, shoreline extraction

1. Introduction

The shoreline, as the zone of contact between the body of water and land, is an interface that continuously changes through time, because cross-shore and along-shore sediment movement, and space, because of the dynamic nature of the water level. Analysis of shoreline variability (or change), erosion and accretion trends is fundamental to a broad range of investigations undertaken by coastal scientists, coastal engineers and managers. For practical purposes, coastal investigators have defined shoreline indicators as a feature that represents its position, such as the vegetation line, and wet-dry sand line between the physical features, or, for example, mean high water line. In this reasoning, shoreline definition and delineation depend on the selected shoreline indicator, but the interpretation of these indicators tends to be subjective.

Since 1920's, aerial photographs have been used to document shoreline position and change. Aerial photographs are first transformed to map coordinates using ground control points and then a proxy for shoreline is digitized. Aerial photographs were generally collected more frequently than maps were made, and therefore, may be used to develop a more detailed understanding of short-term shoreline variability. For unrectified aerial photographs, accuracy within or between images is limited by scale differences (caused by aircraft altitude changes), by camera geometry, by ground relief and by the precision of the digitizing equipment and of the operator in following the trace of (any) water level [1]. Since the errors in measuring a shoreline from aerial photographs are not independent, cumulative errors can be large, but can be eliminated or reduced before features are identified within the image by using recent techniques involving softcopy photogrammetry where digital stereo images are used to georeference the image and remove distortion.

Shorelines have also been measured from ground-based surveys of cross-shore profiles of beach elevations. Since these surveys are relative inexpensive to perform, closely spaced profiles can be collected frequently and used for detailed studies of short-term variations in shoreline position over a limited region. While ground-based profiling techniques may yield an accurate measure of shoreline location, the measurements are spatially limited due to the intensive labor requirement of profiling. More recently, shoreline position has been measured using vehicle-mounted, ground-based GPS surveys. All-terrain vehicles equipped with GPS antennae can quickly survey shore-parallel and shore-normal profiles, a single transect along the length of the beach or a complete, detailed mapping of beach topography. Horizontal accuracy of shoreline positions measured using these techniques depends on, among other things, GPS accuracy, proximity of survey lines to the exact location of the shoreline and beach slope.

While the spatial coverage of the vehicle-based GPS ground surveys can be very extensive, it is still somewhat limited compared to the capabilities of an airborne system. Recent developments in GPS and scanning airborne laser capabilities have made available extensive data sets of fully three-dimensional beach topography. These highly accurate and spatially dense surveys allow the possibility of making an objective and detailed determination of regional-scale shoreline position. Using laser data to quantify shoreline position and change over regional scales will contribute to an improved understanding of large-scale coastal behavior of both long and short-term scales.

In order to accurately quantify the variability of large-scale coastal changes and to obtain a clearer understanding of the processes driving these changes, detailed measurement of large-scale morphology over regional scales is required. While change occurs over the entire activity profile, the horizontal location and movement of the shoreline are two of the most commonly chosen variables of large-scale beach morphology and serve as direct indicators of erosion and accretion. Topographic maps, rectified aerial photographs and traditional beach profiles have been the most common source for long-term, large-scale measures of shoreline position [2]. These historical shoreline locations are often compared to present shoreline locations to calculate rates of long-term shoreline change. Because of their long record length, maps and aerial photographs are invaluable in quantifying long-term shoreline change.

Quantification of shoreline location usually involves a number of assumptions [6]. Therefore, all estimates will have errors associated with both the technique for measuring shoreline position and the assumptions made regarding the definition of the shoreline. Traditional methods using aerial photographs for shoreline measurement often involved non-stereo photography with no vertical information. In this case, relationships must be assumed between some identifiable horizontal feature and its assumed vertical elevation. Digitizing an aerial photograph is a very tedious and time-consuming operation still present in most of the cartographic and hydrographic agencies in the world. Also, the human element is still required in the process of image interpretation. Photo interpretation is the process of extracting enough information from an image to create meaningful map presentations. Coastline information is usually the strongest edge present in an image, either in optical or radar images. An edge is a point that indicates the presence of an intensity change in certain conditions and, consequently, a boundary is a collection of connected edge points [4, 5, and 6]. Because optical images receive energy coming from the sun reflected from the earth in various channels of the electromagnetic spectrum, the procedures to extract shapes and edges is more straightforward than using a single channel active remote sensing image (radar images).

2. Automatic extraction of shorelines

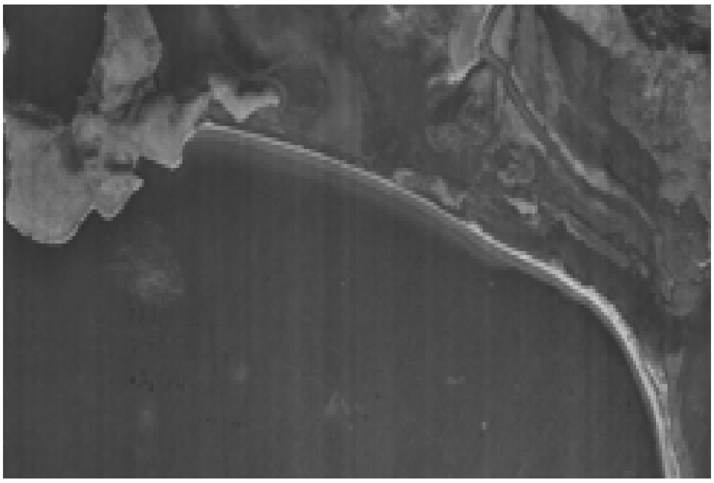
The purpose of the present study is to compare three different shoreline detection algorithms to automatically extract the shoreline from aerial photographs. To motivate the study, two aerial photographs of a coastal region in Greece were selected with scale 1:42,000 (1945) and 1:8,000 (2003) (Figure 1). Both photos cover the same coastal area and were scanned using 600dpi resolution. Since the shoreline was not easy to detect on the two digital images, the ER Mapper programme was used to intensify the edges along the direction NW-SE and SW-NE of the 1945 and 2003 air photograph respectively. The following steps were followed to detect and, finally, extract the shoreline:

<u>Phase A: Editing of the picture before the algorithm implementation.</u>

Step 1: Scanning the images

Step 2: Test of different filters that will suit better to each air photograph (in order to have the best results depending on the direction of the shoreline as well as their characteristics).

Step 3: Scanning of the proper filter for each air photograph.



(a)

(b)

Figure 1.The 1945 (a) and 2003 (b) air photographs

Phase B: Editing of the picture with the Matlab programme.

Step 4: Noise reduction by using Matlab's filter *medfilt2.*

Step 4a: Trial of the filter for a 5X5 pixel area

Step 4b: Trial of the filter for a 8X8 pixel area

Step 5: Histogram equalization for both air photographs

Step 6: Rejection of the image that was created of the 8X8 pixel area because of the level of distortion.

Step 7: Division of the image into blocks by using the function:

$$f = @ (x)\ unit8\ (round\ (mean2(x) * ones\ (size\ (x)))) \quad (1)$$

The function calculates the mean of the numbers of the pixels that belong to the block and assigns this value to every pixel that belongs to the block.

- From this point on, every change made concerns both the image divided in blocks as well as the image without the blocks.

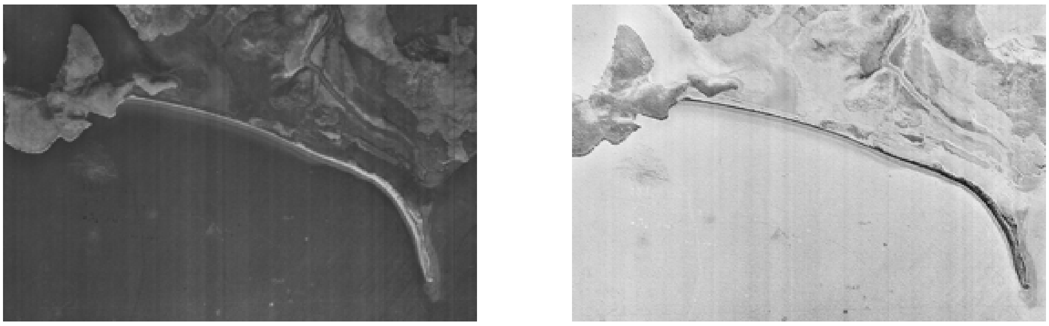
Step 8: Edge detection by using Matlab's function *edge.*

Step 8a: Use of the algorithm “canny”
Step 8b: Use of the algorithm “prewitt”
Step 8c: Use of the algorithm “zerocross”
A 5 X 5 and 3 X 3 filters were implemented on the 1945 and 2003 air photographs respectively:

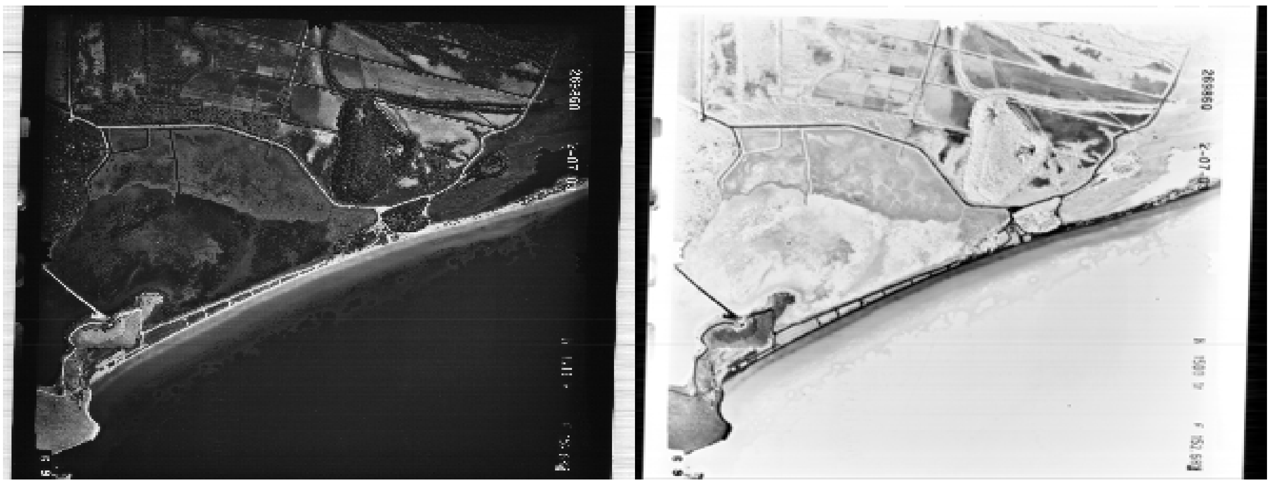
0	0	0	-1	-1
0	0	0	-1	-1
0	0	10	0	0
-1	-1	0	0	0
-1	-1	0	0	0

-1	0	0
0	0	0
0	0	-1

The results of the filter implementation are given in Figure 2.



(a)

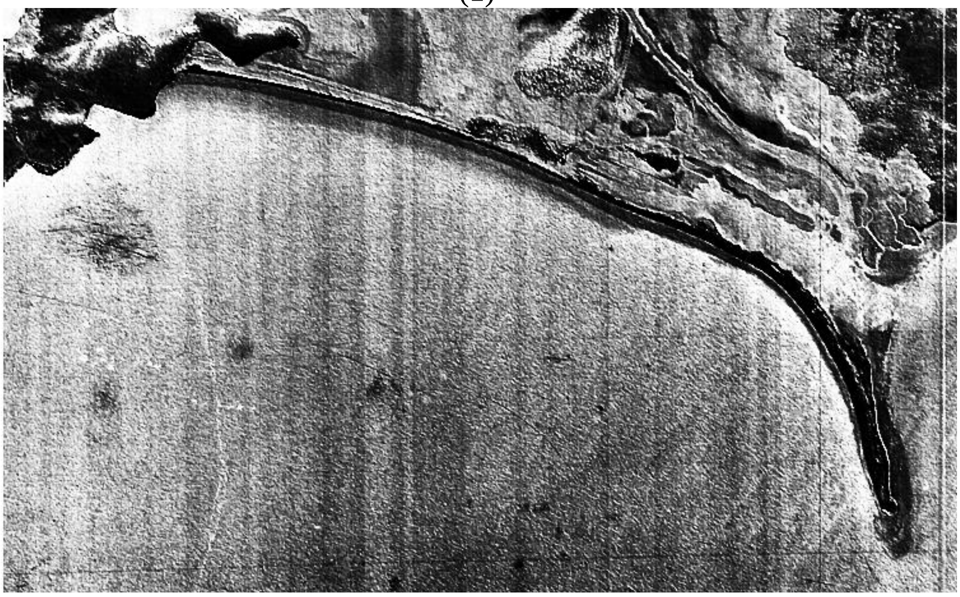


(b)

Figure 2. Filter implementation on the scanned air photographs

Since it is desirable to intensify the contrast between the water and the land in order to extract the shoreline with the greatest possible accuracy, the edge strength image is thresholded to obtain a binary image. The results are given in Figure 3.

(1)



(2)

Figure 3.Different stages in thresholding a strengthened image (1 and 2)

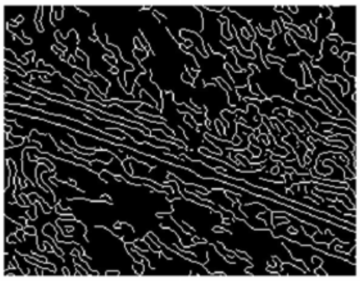
For better and faster image processing, blocks of 5X5 pixels were introduced and the previous filters were again exercised using the following Matlab code:

```
>> BW1 = edge(photoclean,'canny');
>> BW2 = edge(photoclean2,'canny');
>> BW3 = edge(photoclean,'prewitt');
>> BW4 = edge(photoclean2,'prewitt');
>> BW5 = edge(photoclean,'zerocross',0);
>> BW6 = edge(photoclean2,'zerocross',0);
```

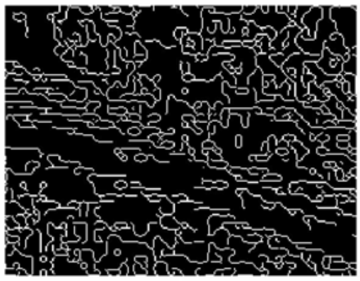
Finally, the edge detection algorithm was engaged to detect and extract the pixel curve which will be converted to vector form by fitting piecewise segment to it.

3. Results

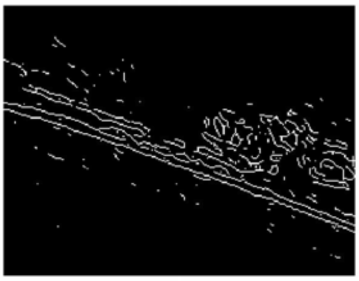
In Figure 4 (a, b and c) and in Figure 5 (a, b and c) the 1945 and 2003 air photographs are presented after being processed by the edge detection algorithm using the Canny (a), Prewitt (b) and zerocross (c) methods respectively [4]. In the left column the results are with no block division and the right column with block division.



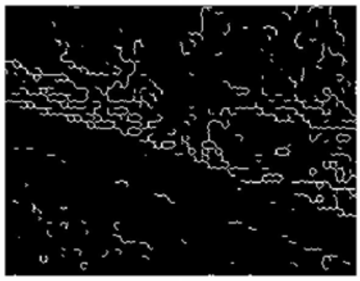
a. Canny (no blocks)



b. Canny (with blocks)

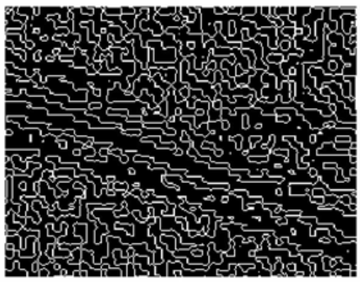


b. Prewitt (no blocks)



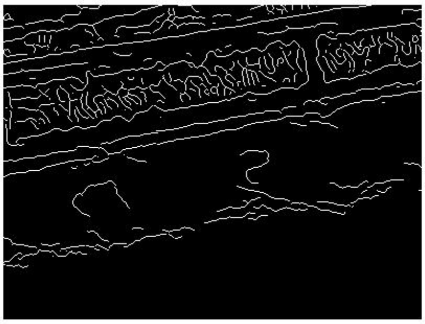
b. Prewitt (with blocks)

c. zerocross (no blocks)



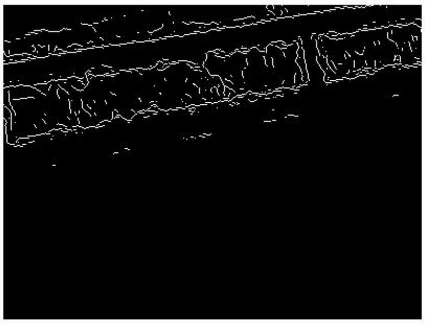
c. zerocross (with blocks)

Figure 4. 1945 air photograph: the edge detection algorithm results with no blocks (left) and with blocks (right) being processed by Canny, Prewitt and zerocross methods.



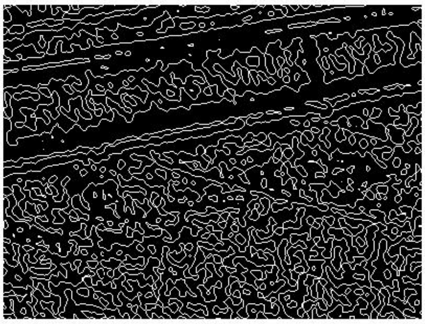
a. Canny (no blocks)

b. Canny (with blocks)

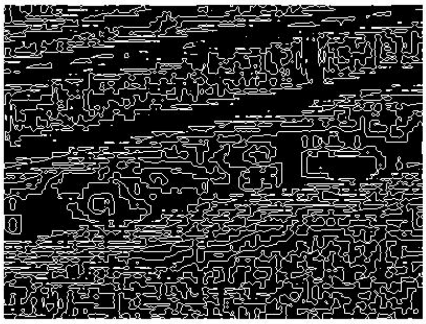


b. Prewitt (no blocks)

b. Prewitt (with blocks)



c. zerocross (no blocks)

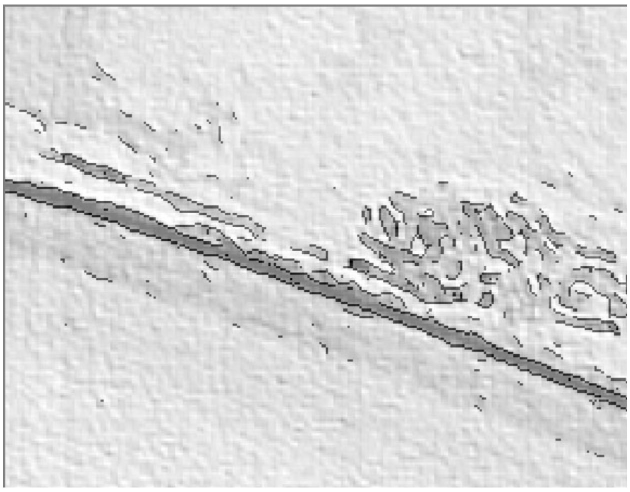


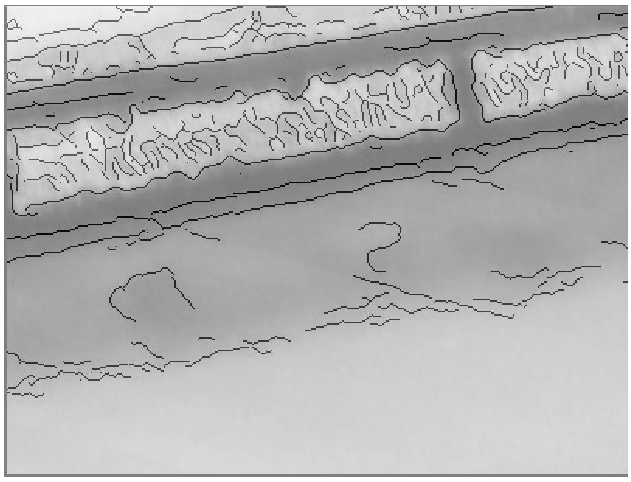
c. zerocross (with blocks)

Figure 5. 2003 air photograph: the edge detection algorithm results with no blocks (left) and with blocks (right) being processed by Canny, Prewitt and zerocross methods.

4. Conclusions

From the above given analysis and results it is evident that as far as the 1945 air photograph is concerned, the Prewitt method with no block division extract the shoreline with the least ambiguity and Canny method with no block division for the 2003 air photograph (Figure 6). The common procedure of dividing the image into blocks in order to accelerate the procedure is difficult to be used in the case of shoreline detection as the results showed the precision of the detection is very bad and sometimes the shoreline cannot even been detected.





1945 air photograph
Prewitt method (no blocks)

2003 air photograph
Canny method (no blocks)

Figure 6. Shoreline extraction from 1945 and 2003 air photographs with Prewitt and Canny methods and no blocks.

As the filters for edge and contrast enhancement are concerned, the idiomorphic nature of each image does not allow having a highly standardized procedure for every image. The condition of the scanned image and the exact direction of the beach are the main factors that prevent this standardization.

Finally, the scale of the image is a very important factor for shoreline detection and extraction because in high resolution images the levels of gray change very slowly in small depths and is very difficult to find the ideal algorithm which will detect the correct change of tones.

5. References

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